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oxygen. This, in relation to the earth's mass, is .0000008825.

5. *Unoxidized carbon.* — This occurs not only in coal-beds, but in pyroschists and petroleum. We find that the oxidation of a layer of carbon 0.7123 metre in thickness would use up all the oxygen in the atmosphere. A layer 2.252 metres thick, and having a specific gravity of 1.25, if converted into carbon dioxide, would exert a pressure of one atmosphere. This would amount to 2,267,000 tons of 2,240 pounds each on a square mile. Mr. J. L. Mott calculates that the amount of unoxidized carbon per square mile cannot be less, and is probably many times greater, than 3,000,000 tons. If we adopt this determination, it will imply a depth of 0.982 metre, and the proportion of the earth's mass will be .00000036318. This is the amount of carbon dioxide which must be decomposed to yield a layer of carbon over the earth only a trifle over three feet in thickness, while it is probable that the carbonaceous deposits of the earth's crust exceed this. Now, it will hardly be maintained that the uncombined carbon of the earth's crust was derived from any other source than the atmosphere, and mostly through the agency of vegetation. The earth's atmosphere must therefore have contained all this amount of carbon dioxide. With the fixation of the carbon, the freed oxygen, it may be said, might have been employed, as far as it would go, in the formation of ferric oxide, whose demands upon the atmosphere have just been computed; but, as it would only satisfy $\frac{1}{309}$ of those demands, it is hardly necessary to consider the question.

6. *Meteoric contributions.* — If, as commonly assumed, 400,000,000 meteors enter our atmosphere daily, an average weight of ten grains each would amount to a yearly addition of 93,170 tons. This, in 100,000,000 years, would amount to .000000001542 of the earth's mass, and would form a film .292, or nearly $\frac{2}{7}$, of an inch thick, having a density of 2.5.[1]

Gathering together these various contributions to the earth's mass during 100,000,000 years, we have the following: —

1. CO_2 represented by the carbonates	.0003806
2. CO_2 fixed in kaolinization of felspars	.0000175826
3. CO_2 fixed in decay of hornblendic and augitic rocks	.0000403209
4. O fixed in conversion of ferrous oxide	.0000008825
5. CO_2 represented by uncombined carbon	.00000036318
6. Meteoric contributions	.000000001542
Aggregate	.000439750722

This is an addition of $\frac{1}{2416}$ to the earth's mass; and, in the present state of knowledge, it does not appear on what grounds assent can be withheld from the result, or some result of similar purport. It must be left with the astronomer to determine what relation this increase may sustain to the moon's acceleration in its orbit and to other phenomena. It may be noted, however, that the remote secular recession and retardation of the moon, which G. H. Darwin has recently brought to view, would have been delayed by the cause here considered, and the time required for the attainment of the moon's present relations would have been prolonged, but to what extent remains to be determined.

The evidences disclosed by these recent researches, of the slow accession of gaseous and solid matters to the earth, possess a profound interest. It would almost seem that the earth's atmosphere is only so much of the intercosmical mixture of gases and vapors as the earth's mass is capable of condensing around it, and that the proportions of these gases are determined separately, each by its own weight and elasticity and by its relative abundance in space; so that, as any one becomes diminished by fixation in the planetary crust, new supplies arrive to keep the ratio constant. As under this view it is apparent that an atmosphere should be accumulated around the moon, even after the saturation of the pores of its rocks, it may be said that the moon's mass and volume are such that her atmosphere would possess only $\frac{1}{36}$, or, according to Neison, $\frac{1}{50}$, the density of the earth's atmosphere; and this degree of tenuity might reduce the lunar atmospheric refraction to the small value actually observed. ALEXANDER WINCHELL.

[1] The value given for this film in a note, p. 14, in my 'World-life,' should be multiplied by 365¼.

Regulation of electromotive force.

In one of the articles — the first, I think — recently published in SCIENCE (ii. 642) upon the subject of the electric light on the U. S. fish-commission steamer Albatross, the writer tells us that the brilliancy of the Edison incandescent lamps is kept constant, when other lamps upon the circuit are lighted or extinguished, by placing an adjustable resistance in the circuit of the field-magnets of the dynamo-electric machine, 'whereby the internal and external resistances are balanced.'

The importance of the subject scarcely seems to warrant any more space being devoted to it than already has been. But the point that I bring up is not an immaterial one, such as whether the engine is on the port or the starboard side of the vessel: it is a question which involves interesting and important physical principles.

The reason an adjustable resistance is required in the field-circuit of an Edison dynamo, in order to maintain a steady incandescence of the lamps, results from the fact that the armature has some resistance. This resistance is quite small, to be sure, but it has a considerable effect, nevertheless.

In order that a multiple arc system should be perfect, so that the dynamo or generator would require no adjustment or regulation when lamps were turned on or off the circuit, it would be necessary that this generator should have absolutely no resistance: for, if it were possible to reduce the internal resistance to zero, then there would be no fall of potential within the machine itself; that is, the fall of potential would all be in the external circuit, and the difference of potential between the poles of the generator would be equal to the total electromotive force of the circuit. In that case, all that is necessary is to keep the electromotive force constant; and then it follows, that any number of the lamps in the system may be lighted or put out without producing any fluctuation whatever in the light of the other lamps, because the incandescence of a given lamp depends only upon the electromotive force with which it is supplied. Now, we know that the electromotive force generated by a dynamo is constant, provided that the speed of rotation of its armature, and the intensity of the field-magnetism, are kept constant. The armature is maintained at a constant speed because it is driven by a steam-engine furnished with a governor, the function of which is to secure a constant speed;[1] and the field-magnets have a constant strength because the current which excites them is constant, since this current, like the current in the lamps, is produced by an electromotive force, which, by hypothesis, is constant.

Let us now consider the case where the resistance of the armature is not zero (to which, of course, it

[1] The speed would remain constant, but the *power* required would increase with the number of lamps in circuit.

never could be reduced), but is some small fraction of an ohm (say, .2 ohm), and suppose that there is a single lamp of 140 ohms' resistance in circuit, and that the electromotive force is 100 volts: then $\frac{140}{140.2} \times 100 = 99\frac{6}{7}$ volts will be the fall of potential in the lamps, and only $\frac{1}{7}$ volt in the armature. But suppose that there are 70 lamps of the same resistance (140 ohms) in circuit, instead of a single one: then the external resistance will be reduced to $\frac{140}{70} = 2$ ohms, and the fall of potential in the lamps will only be $\frac{2}{2.2} \times 100 = 90\frac{10}{11}$ volts, and $9\frac{1}{11}$ volts in the armature.

Thus we see, that, when the number of lamps in circuit is increased from 1 to 70, the difference of potential available in the lamps is decreased from $99\frac{6}{7}$ to $90\frac{10}{11}$ volts, a reduction of almost one-tenth; in consequence of which the candle-power of the lamps would be lowered at least one-third, and probably one-half. Of course, variations in the brightness of the lamps of one-third, or one-tenth, or even one-twentieth, would not be permissible: therefore, in order to maintain the required steadiness of the light, it is necessary to raise the electromotive force of the dynamo as more lamps are put on, and to lower it as lamps are taken off. This is done by increasing or diminishing the strength of current in the circuit of the field-magnets by means of a resistance-box interposed in the circuit. This regulation of the electromotive force of dynamos by controlling the resistance of the field-circuit may be, and in fact has been, made automatic; but up to the present time it has more generally been done by hand.

In what has gone before, I have said nothing about the resistance of the conductors which convey the current from the dynamo to the lamps. The effect of the resistance of any conductor which is *common to two or more lamps* — one of the main conductors, for example — is precisely the same as the effect of the resistance of the armature, which has been discussed above; but when a conductor supplies only a *single* lamp, then it does not have this effect. Of course there is a loss or fall of potential due to the resistance of the individual conducting-wires of each lamp; and of course the fall of potential in the lamp itself, and consequently its brightness, are thereby reduced. But this resistance does not introduce any *irregularity:* its effect in diminishing the light of the lamps is constant.

Let us suppose that a conductor having a resistance of 140 ohms feeds a single lamp of 1.4 ohms' resistance: then the loss in this conductor will be 1% of the useful fall of potential. But suppose that we now put 10 more lamps in circuit: then the loss in the conductors will be increased to over 10%; and assuming the useful fall of potential to be 100 volts, with a single lamp in circuit, it will only be about 90 volts with 11 lamps. The candle-power of the first lamp would drop at least 25% or 30% when the other 10 lamps were added. Thus it is, that, in a multiple arc system of electric lighting, any resistance which is common to a number of lamps, whether in the armature or the conductors, causes fluctuations in the light of the lamps when other lamps are put on or off; whereas the resistance of the individual conductors of each lamp produces a loss of potential which is a constant fraction of the total potential, but does not introduce any unsteadiness.

F. B. CROCKER.

Osteology of the cormorant.

With respect to Mr. Jeffries' criticism (SCIENCE, ii. 739) of my paper on cormorants, I beg to say that the occipital style of the cormorant is not an ossification in the tendon of any muscle; that he is entirely wrong in his view of the homologies of what I call a patella; and that, furthermore, I find myself misquoted more than once.

R. W. SHUFELDT.

A dog plans and executes with reference to the future.

Six weeks ago Prof. J. B. Thayer of this place returned from Ree Heights, Dakota, bringing with him one of a litter of eight pups raised by a slut of the setter breed. The story which he relates to me of this pup's mother is, it appears to me, worthy of record.

The good mother appears to have discharged her arduous duties as only a mother can, and arrived with her eight babes at the time when they should be weaned. At this juncture, judging from the events reported to have followed, she seems to have conceived the idea that too many dogs were occupying the same claim, and that a distribution was desirable. Accordingly, she started one morning with three of her pups, and was observed by Miss Rosa Cheney, now of this place, running in the road toward their claim at a rate which made it impossible for the pups to keep pace with her. The dwelling where she lived, and another shanty on the adjoining corner of another claim, are situated one mile and three-fourths from the dog's home. The mother reached the claims in advance of her babes, but no sooner had they arrived than she hurried on at her best pace. Miss Cheney reports that "the puppies came up all out of breath, and apparently too tired to continue; but the smallest of the three followed on." Another claim was reached three-fourths of a mile beyond; and here Miss Cheney observed the mother stop until her panting babe came up, when she immediately set off again. A quarter of a mile beyond the last claim, the mother was observed to make a third halt as before, and then to pass on beyond the range of vision, towards Ree Heights, with the puppy still following her. Two days later the persistent mother, with her more persistent babe, was observed coming back; and Miss Cheney tells me that the little puppy appeared almost dead from fatigue.

Some days later the dog led off two more of her pups, and succeeded in leaving them both; but in the mean time the two puppies left the first day were returned. A pup was also left at Professor Thayer's claim, but was returned, and exchanged for another. Both Professor Thayer and Miss Cheney assure me that other efforts of the same kind were made by this dog, but with what results they are unable to say.

After the puppies had been distributed, they were not forgotten; for the old dog used often to go and play with them. Professor Thayer mentions one instance of her coming and playing with the puppy left at his claim until it was very tired, when she lay down by the side of it; but, after it had gone to sleep, she quietly walked to the opposite side of the house, and then hurried away in the opposite direction from home for a distance of about forty rods, when she turned and went directly there, thus showing quite clearly that the thought of distributing her puppies was still uppermost in her mind.

What events may have awakened this desire on the part of the mother, or what reasons she had for her acts, we do not know; but in her own mind I have no doubt the case was urgent and the way clear, if